APPENDIX 2. SIMULATOR VALIDATION TESTS

1. DISCUSSION. Simulator performance and system operation must be objectively evaluated by comparing the results of tests conducted in the simulator to airplane data unless specifically noted otherwise. To facilitate the validation of the simulator, a multichannel recorder, line printer, or other appropriate recording device acceptable to the NSPM should be used to record each validation test result. These recordings should then be compared to the airplane source data.

The ATG provided by the operator must describe clearly and distinctly how the simulator will be set up and operated for each test. Use of a driver program designed to automatically accomplish the tests is encouraged for all simulators. Self testing of simulator hardware and programming to determine compliance with all simulator requirements is specified by FAR Part 121, Appendix H, for Phase III (Level D) simulators. It is not the intent and it is not acceptable to the FAA to test each simulator subsystem independently. Overall integrated testing of the simulator must be accomplished to assure that the total simulator system meets the prescribed standards. A manual test procedure with explicit and detailed steps for completion of each test must also be provided.

The tests and tolerances contained in this appendix must be included in the operator's ATG. Levels B, C, and D simulators must be compared to flight test data except as otherwise specified. For airplanes certificated prior to June 1980, an operator may, after reasonable attempts have failed to obtain suitable flight test data, indicate in the ATG where flight test data are unavailable or unsuitable for a specific test. For such a test, alternative data should be submitted to the NSPM for approval. Submittals for approval of data other than flight test must include an explanation of validity with respect to available flight test information.

The Table of Validation Tests of this appendix generally indicates the test results required. Unless noted otherwise, simulator tests should represent airplane performance and handling qualities at operating weights and centers of gravity (CG) typical of normal operation. If a test is supported by airplane data at one extreme weight or CG, another test supported by airplane data at midconditions or as close as possible to the other extreme should be included. Certain tests which are relevant only at one extreme CG or weight condition need not be repeated at the other extreme. Tests of handling qualities must include validation of augmentation devices.

Simulators for highly augmented airplanes will be validated both in the unaugmented configuration (or failure state with the maximum permitted degradation in handling qualities) and the augmented configuration. Where various levels of handling qualities result from failure states, validation of the effect of the failure is necessary. Requirements for testing will be mutually agreed to between the operator and the NSPM on a case-by-case basis.

SIMULATOR VALIDATION TESTS (Cont'd)

In the case of simulators approved under previous advisory circular, the tolerances of this appendix may be used in subsequent recurrent evaluations for any given test providing the operator has submitted a proposed ATG revision to the NSPM and has received FAA approval.

2. TEST REQUIREMENTS. The ground and flight tests required for qualification are listed in the Table of Validation Tests. Computer generated simulator test results should be provided for each test. The results should be produced on a multichannel recorder, line printer, or other appropriate recording device acceptable to the NSPM. Time histories are required unless otherwise indicated in the Table of Validation Tests.

Flight test data which exhibit rapid variations of the measured parameters may require engineering judgment when making assessments of simulator validity. Such judgment must not be limited to a single parameter. All relevant parameters related to a given maneuver or flight condition must be provided to allow overall interpretation. When it is difficult or impossible to match simulator to airplane data throughout a time history, differences must be justified by providing a comparison of other related variables for the condition being assessed.

a. Parameters, Tolerances, and Flight Conditions. The Table of Validation Tests of this appendix describes the parameters, tolerances, and flight conditions for simulator validation. When two tolerance values are given for a parameter, the less restrictive may be used unless otherwise indicated.

If a flight condition or operating condition is shown which does not apply to the qualification level sought, it should be disregarded. Simulator results must be labeled using the tolerances and units given.

b. Flight Conditions Verification. When comparing the parameters listed to those of the airplane, sufficient data must also be provided to verify the correct flight condition. For example, to show that control force is within ±5 pound (2.225 daN) in a static stability test, data to show the correct airspeed, power, thrust or torque, airplane configuration, altitude, and other appropriate datum identification parameters should also be given. If comparing short period dynamics, normal acceleration may be used to establish a match to the airplane, but airspeed, altitude, control input, airplane configuration, and other appropriate data must also be given. All airspeed values should be clearly annotated as to indicated, calibrated, etc., and like values used for comparison.

NOTE: The application of this appendix to simulator validation requires reference to FAR Part 121, Appendix H, to acquire full knowledge of simulator criteria for approval.

TABLE OF VALIDATION TESTS

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
1. PERFORMANCE							
a. TAXI							
(1) Minimum Radius Turn	±3 Feet (0.9m) or 20% of Airplane Turn Radius	Ground/Takeoff		IR	IR	IR	
(2) Rate of Turn vs. Nosewheel Steering Angle	±10% or ±2°/sec. Turn Rate	Ground/Takeoff		IR	IR	IR	
b. TAKEOFF							
(1) Ground Acceleration Time and Distance	±5% Time and Distance or ±5% Time and ±200 Feet (61 Meters) of Distance	Ground/Takeoff	IR	IR	IR	IR	Unfactored aircraft certification data may be used. Acceleration Time and Distance should be recorded for a minimum of 80% of total segment. (Brake release to V_r).
(2) Minimum Control Speed Ground (V_{mcg}) Aerodynamic Controls Only per Applicable Airworthiness Standard or Low Speed, Engine Inoperative Ground Control Characteristics	Maximum Airplane Lateral Deviation ±25% or ±5 Feet (1.5 Meters)	Ground/Takeoff	IR	IR	IR	IR	Engine failure speed must be within ±1 knot of airplane engine failure speed.
(3) Minimum Unstick Speed or equivalent as provided by the airplane manufacturer	±3 Kts Airspeed ±1.5° Pitch	Ground/Takeoff	IR	IR	IR	IR	V_{mu} is defined as that speed at which the last main landing gear leaves the ground. Main landing Gear Strut Compression or equivalent air/ground signal should be recorded. Record as a minimum from 10 Kts before start of rotation.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
1. **PERFORMANCE (TAKEOFF con't)**							
(4) Normal Takeoff	±3 Kts Airspeed ±1.5° Pitch ±1.5° Angle of Attack ±20 Feet (6 Meters) Altitude ±5.0 lb (2.224 dN) or ±10% Column Force*	Ground/Takeoff and First Segment Climb	IR	IR	IR	IR	Record Takeoff profile from brake release to at least 200 ft. (61 Meters) Above Ground Level (AGL). *Applies only to reversible control systems.
(5) Critical Engine Failure on Takeoff	±3 Kts Airspeed ±1.5° Pitch, ±1.5° Angle of Attack ±20 Feet (6 Meters) Altitude ±2° Bank and Sideslip Angle ±5.0 lb (2.224 dN) or ±10% Column Force* ±5.0 lb (2.224 dN) or ±10% Rudder Pedal Force* ±3.0 lb (1.334 dN) or 10% Aileron Wheel Force*	Ground/Takeoff and First Segment Climb	IR	IR	IR	IR	Record Takeoff profile at maximum takeoff weight to at least 200 ft. (61 Meters) AGL. Engine failure speed must be within ±3 Kts of airplane data. *Applies only to reversible control systems.
(6) Crosswind Takeoff	±3 Kts Airspeed ±1.5° Pitch, ±1.5° Angle of Attack ±20 Feet (6 Meters) Altitude ±2° Bank and Sideslip Angle ±5.0 lb (2.224 dN) or ±10% Column Force* ±5.0 lb (2.224 dN) or ±10% Rudder Pedal Force* ±3.0 lb (1.334 dN) or 10% Aileron Wheel Force*	Ground/Takeoff and First Segment Climb	IR	IR	IR	IR	Record Takeoff profile to at least 200 ft. (61 Meters) AGL with same relative wind profile as airplane test. *Applies only to reversible control systems.
(7) Rejected Takeoff	Overall Distance ± ? Braking Effort ± ? (To Be Determined)	Ground	IR	IR	IR	IR	Auto brakes will be used where applicable. Maximum braking effort, Auto or Manual.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
1. PERFORMANCE (Con't)							
c. CLIMB							
(1) Normal Climb All Engines Operating	±3 Kts Airspeed ±5% or ±100 FPM (0.5 Meters/Sec.) Climb Rate	Climb With All Engines Operating	IR	IR	IR	IR	May be a Snapshot Test. Manufacturer's gross climb gradient may be used for flight test data.
(2) One Engine Inoperative Second Segment Climb	±3 Kts Airspeed ±5% or ±100 FPM (0.5 Meters/Sec.) Climb Rate, but not less than the FAA Approved Flight Manual Rate of Climb	Second Segment Climb With One Engine Inoperative	IR	IR	IR	IR	May be a Snapshot Test. Manufacturer's gross climb gradient may be used for flight test data. Test at weight altitude, temperature limited conditions.
(3) One Engine Inoperative Approach Climb for Airplanes With Icing Accountability per Approved AFM	±3 Kts Airspeed ±5% or ±100 FPM (0.5 Meters/Sec.) Climb Rate, but not less than the FAA Approved Flight Manual Rate of Climb	Approach Climb With One Engine Inoperative	IR	IR	IR	IR	May be a Snapshot Test. Manufacturer's gross climb gradient may be used for flight test data. Use near maximum landing weight.
d. STOPPING							
(1) Deceleration Time and Distance, Wheel Brakes Using Manual Braking, Dry Runway (No Reverse Thrust)	±5% of Time. For distance up to 4000 Feet (1220 m.) ±200 Feet (61 m.) or ±10% whichever is smaller. For distance greater than 4000 Feet (1220 m.) ±5% of distance.	Landing	IR	IR	IR	IR	Time and Distance should be recorded for at least 80% of the total segment (TD to Full Stop). Brake system pressure should be available.
(2) Deceleration Time and Distance, Reverse Thrust, Dry Runway (No Wheel Braking)	±5% Time and the Smaller of ±10% or 200 Feet (61 Meters) of Distance	Landing	IR	IR	IR	IR	Time and Distance should be recorded for at least 80% of the total demonstrated reverse thrust segment.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
1. PERFORMANCE (STOPPING Con't)							
(3) Stopping Time and Distance, Wheel Brakes, Wet Runway (No Reverse Thrust)	Representative Stopping Time and Distance	Landing			I	I	FAA approved Airplane Flight Manual (AFM) data is acceptable.
(4) Stopping Time and Distance, Wheel Brakes, Icy Runway (No Reverse Thrust)	Representative Stopping Time and Distance	Landing			I	I	FAA approved AFM data is acceptable.
e. ENGINES							
(1) Acceleration	T_i ±10% T_t ±10%	Approach or Landing	IR	IR	IR	IR	T_i = Total time from initial throttle movement until a 10% response of a critical engine parameter. T_t = Total time from T_i to 90% go-around power. Critical engine parameter should be a measurement of power (N_1, N_2, EPR, Torque, etc.) Plot from flight idle to go-around power for a rapid (slam) throttle movement.
(2) Deceleration	T_i ±10% T_t ±10%	Ground/Takeoff	IR	IR	IR	IR	Test from maximum takeoff power to 10% of maximum takeoff power (90% decay in power). Time history should be provided.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
2. HANDLING QUALITIES							
a. STATIC CONTROL CHECKS**							
(1) Column Position vs. Force and Surface Position Calibration	±2 lbs (0.89 daN) Breakout ±5 lbs (2.224 daN) or ±10% Force ±2° Elevator	Ground	IR	IR	IR	IR	Uninterrupted control sweep, stop to stop.
(2) Wheel Position vs. Force and Surface Position Calibration	±2 lbs (0.89 daN) Breakout ±3 lbs (1.334 daN) or ±10% Force ±1° Aileron ±3° Spoiler	Ground	IR	IR	IR	IR	Uninterrupted control sweep, stop to stop.
(3) Pedal Position vs. Force and Surface Position Calibration	±5 lbs (2.224 daN) Breakout ±5 lbs (2.224 daN) or ±10% Force ±2° Rudder	Ground	IR	IR	IR	IR	Uninterrupted control sweep, stop to stop.
(4) Nosewheel Steering Force & Position	±2 lbs (0.89 daN) Breakout ±3 lbs (1.334 daN) or ±10% Force ±2° Nosewheel Angle	Ground	IR	IR	IR	IR	Uninterrupted control sweep, stop to stop.
(5) Rudder Pedal Steering Calibration	±2° Nosewheel Angle	Ground	IR	IR	IR	IR	

**Column, wheel, and pedal position vs. force shall be measured at the control. An alternate method acceptable to the NSPM in lieu of the test fixture at the controls is to instrument the simulator in an equivalent manner to the flight test airplane. The force and position data from this instrumentation can be directly recorded and matched to the airplane data. Such a permanent installation would eliminate the need for installation of external devices.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
2. HANDLING QUALITIES (STATIC CONTROL CHECKS Con't)							
(6) Pitch Trim Calibration Indicator vs. Computed	±0.5° of Computer Trim Angle ±10% Trim Rate	Ground and Go-Around	IR	IR	IR	IR	Measure trim rate for go-around. Trim rate input and surface rate time history is appropriate.
(7) Alignment of Power Lever Angle vs. Selected Engine Parameter (EPR, N_1, Torque, etc.)	±5° of Power Lever Angle	Ground	IR	IR	IR	IR	Simultaneous recording for all engines. A 5° tolerance applies against airplane data and between engines. May be Snapshot Test.
(8) Brake Pedal Position Vs. Force	±5 lb (2.224 daN) or 10% ±10% or 150 psi (1033 kPa) brake hydraulic pressure		IR	IR	IR	IR	Simulator computer output results may be used to show compliance. Relate hydraulic system pressure to pedal position in a ground static test.
b. DYNAMIC CONTROL CHECKS**							
(1) Pitch Control	±10% of time for first zero crossing, and ±10(n+1)% of period thereafter. ±10% amplitude of first overshoot. ±20% of amplitude of 2nd and subsequent overshoots greater than 5% of initial displacement. ±1 overshoot.	Takeoff, Cruise, Landing			IR	IR	Data should be normal control displacement in both directions. Approximately 25% to 50% of full throw. n is the sequential period of a full cycle of oscillation. Refer to paragraph 3 this appendix.

**Column, wheel, and pedal position vs. force or time shall be measured at the control. An alternate method acceptable to the NSPM in lieu of the test fixture at the controls is to instrument the simulator in an equivalent manner to the flight test airplane. The force and position data from this instrumentation can be directly recorded and matched to the airplane data. Such a permanent installation would eliminate the need for installation of external devices.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
2. HANDLING QUALITIES (DYNAMIC CONTROL CHECKS** Con't)							
(2) Roll Control	Same as (1) above.	Takeoff, Cruise, Landing			IR	IR	Data should be normal control displacement. Approximately 25% to 50% of full throw.
(3) Yaw Control	Same as (1) above.	Takeoff, Cruise, Landing			IR	IR	Data should be normal control displacement. Approximately 25% to 50% of full throw.
c. LONGITUDINAL							
(1) Power Change Dynamics	±3 Kts Airspeed ±100 Feet (30 Meters) Altitude ±20% or ±1.5° Pitch	Approach to Go-Around	IR	IR	IR	IR	Wing flaps should remain in the approach position. Time history of uncontrolled free response for time increment from 5 seconds before the initiation of the configuration change to 15 seconds after completion of the configuration change.
(2) Flap/Slat Change Dynamics	±3 Kts Airspeed ±100 Feet (30 Meters) Altitude ±20% or ±1.5° Pitch	Retraction, After Takeoff. Extension, Approach to Landing	IR IR	IR IR	IR IR	IR IR	Time history of uncontrolled free response for time increment from 5 seconds before the initiation of the configuration change to 15 seconds after completion of the configuration change.
(3) Spoiler/Speedbrake Change Dynamics	±3 Kts Airspeed ±100 Feet (30 Meters) Altitude ±20% or ±1.5° Pitch	Cruise and Approach	IR	IR	IR	IR	Time history of uncontrolled free response for time increment from 5 seconds before the initiation of the configuration change to 15 seconds after the completion of the configuration change.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
2. HANDLING QUALITIES (LONGITUDINAL Con't)							
(4) Gear Change Dynamics	±3 Kts Airspeed ±100 Feet (30 Meters) Altitude ±20% or ±1.5° Pitch	Takeoff to Second Segment Climb, Approach to Landing	IR	IR	IR	IR	Time history of uncontrolled free response for a time increment of 5 seconds before the initiation of the configuration change to 15 seconds after the completion of the configuration change.
(5) Gear and Flap/Slat Operating Times	±1 second or 10% of Time	Takeoff, Approach	IR	IR	IR	IR	Normal and alternate flaps, extension and retraction. Normal gear, extension and retraction. Alternate gear, extension only.
(6) Longitudinal Trim	±1° Pitch Control (Stab and Elev) ±1° Pitch Angle ±5% Net Thrust or Equivalent	Cruise, Approach, Landing	IR	IR	IR	IR	May be Snapshot Tests.
(7) Longitudinal Maneuvering Stability (Stick Force/g)	±5 lbs (±2.224 daN) or ±10% Column Force or Equivalent Surface	Cruise, Approach, Landing	IR	IR	IR	IR	May be series of Snapshot Tests. Force or surface deflection must be in correct direction. Approximately 20°, 30°, and 45° bank angle should be presented
(8) Longitudinal Static Stability	±5 lbs (±2.224 daN) or ±10% Column Force or Equivalent Surface	Approach					Data for at least 2 speeds above and 2 speeds below trim speed. May be a series of Snapshot Tests.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
2. HANDLING QUALITIES (LONGITUDINAL Con't)							
(9) Stick Shaker, Airframe Buffet, Stall Speeds	±3 Kts Airspeed ±2° Bank for speeds higher than stick shaker or initial buffet	Second Segment Climb and Approach or Landing	IR	IR	IR	IR	Stall Warning Signal should be recorded and must occur in the proper relation to stall.
(10) Phugoid Dynamics	±10% of Period ±10% of Time to 1/2 or Double Amplitude or ±.02 of Damping Ratio	Cruise	IR	IR	IR	IR	Test should include 3 full cycles (6 overshoots after input completed) or that sufficient to determine time to 1/2 amplitude whichever is less.
(11) Short Period Dynamics	±1.5° Pitch or ±2°/sec. Pitch Rate ±.10g Normal Acceleration	Cruise		IR	IR	IR	
d. LATERAL DIRECTIONAL							
(1) Minimum Control Speed, Air (V_{mca}), per Applicable Airworthiness Standard or Low Speed Engine Inoperative Handling Characteristics in Air	±3 Kts Airspeed	Takeoff or Landing (Whichever is most critical in airplane)	IR	IR	IR	IR	V_{mca} may be defined by a performance or control limit which prevents demonstration of V_{mca} in the conventional manner.
(2) Roll Response (Rate)	±10% or ±2°/sec. Roll Rate	Cruise and Approach or Landing					Test with normal wheel deflection (about 30%).

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
2. HANDLING QUALITIES (LATERAL DIRECTIONAL Con't)							
(3) Roll Response to Roll Controller Step Input	±10% or ±2°/sec. Roll Rate	Approach or Landing	IR	IR	IR	IR	Roll rate response.
(4) Spiral Stability	Correct Trend, ±2° Bank or ±10% in 20 Seconds	Cruise	IR	IR	IR	IR	Airplane data averaged from multiple tests may be used. Test for both directions.
(5) Engine Inoperative Trim	±1° Rudder Angle or ±1° Tab Angle or Equivalent Pedal ±2° Sideslip Angle	Second Segment and Approach or Landing	IR	IR	IR	IR	May be Snapshot Tests.
(6) Rudder Response	±2°/sec. or ±10% Yaw Rate	Approach or Landing	IR	IR	IR	IR	Test with stability augmentation ON and OFF. Rudder step input of approximately 25% rudder pedal throw.
(7) Dutch Roll, Yaw Damper OFF	±0.5 sec. or ±10% of Period. ±10% of Time to 1/2 or Double Amplitude or ±.02 of Damping Ratio. ±20% or ±1 sec. of Time Difference Between Peaks of Bank and Sideslip.	Cruise and Approach or Landing		IR	IR	IR	Test for at least 6 cycles with stability augmentation OFF.
(8) Steady State Sideslip	For a given rudder position ±2° Bank, ±1° Sideslip, ±10% or ±2° Aileron, ±10% or ±5° Spoiler or Equivalent Wheel Position	Approach or Landing	IR	IR	IR	IR	May be a series of Snapshot Tests.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
2. HANDLING QUALITIES (Con't)							
e. LANDINGS							
(1) Normal Landing	±3 Kts Airspeed ±1.5° Pitch ±1.5° Angle of Attack ±10% Altitude or ±10 Feet (3 Meters)	Landing		IR	IR	IR	Test from a minimum of 200 ft. (61 Meters) AGL to Nosewheel Touchdown. Derotation may be shown as a separate segment from the time of main gear touchdown.
(2) Crosswind Landing	±3 Kts Airspeed ±1.5° Pitch ±1.5° Angle of Attack ±10% Altitude or ±10 Feet (3 Meters) ±2° Bank Angle ±2° Sideslip Angle or Yaw Angle	Landing		IR	IR	IR	Test from a minimum of 200 ft. (61 Meters) AGL to Nosewheel Touchdown and rollout to 60 Kts. Use near maximum landing weight with same Relative Wind Profile as aircraft test.
(3) One Engine Inoperative Landing	±3 Kts Airspeed ±1.5° Pitch ±1.5° Angle of Attack ±10% Altitude or ±10 Feet (3 Meters) ±2° Bank Angle ±2° Sideslip Angle or Yaw Angle	Landing		IR	IR	IR	Test from a minimum of 200 ft. (61 Meters) AGL to Nosewheel Touchdown.
(4) Directional Control (Rudder Effectiveness) With Reverse Thrust, Symmetric and Asymmetric	±5 Kts Airspeed	Landing		IR	IR	IR	Airplane test data required, however, airplane manufacturer's engineering simulator data may be used for reference data as last resort. Airplanes with demonstrated minimum speed for rudder effectiveness ±5 Kts. Others, test to verify simulator meets conditions demonstrated by airplane manufacturer.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
2. HANDLING QUALITIES (Con't)							
f. GROUND EFFECT							
(1) A Test to Demonstrate Longitudinal Ground Effect	±1° Elevator or Stabilizer Angle ±5% Net Thrust or Equivalent ±1° Angle of Attack ±10% Height/Altitude or ±5 Feet (1.5 m.) ±3 Knots Airspeed ±1° Pitch Attitude	Landing		IR	IR	IR	See paragraph 4, this appendix. A rationale must be provided with justification of results.
3. MOTION SYSTEM							
a. Frequency Response	As specified by operator for simulator acceptance.		IR	IR	IR	IR	Appropriate test to demonstrate Frequency Response required.
b. Leg Balance	As specified by operator for simulator acceptance.		IR	IR	IR	IR	Appropriate test to demonstrate Leg Balance required.
c. Turn Around Check	As specified by operator for simulator acceptance.		IR	IR	IR	IR	Appropriate test to demonstrate Smooth Turn Around required.
d. Characteristic Buffet Motions	See Appendix 1, para 3.f.					IR	Compliance statement required. Test required.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
4. VISUAL SYSTEM - (Note: Refer to Appendix 3 for additional visual tests.)							
a. Visual Ground Segment (VGS)	±20% Threshold lights must be visible if they are in the visual segment. (See example in Comments.)	Landing. Static at 100 ft. (30 Meters) Wheel Height Above Touchdown Zone on Glide Slope. Runway Visual Range = 1200 Ft. or 350 Meters.	IR	IR	IR	IR	The ATG should indicate the source of data, i.e., ILS G/S antenna location, pilot eye reference point, cockpit cutoff angle, etc., used to make visual ground segment scene content calculations. Tolerance Example: If the calculated VGS for the airplane is 840 ft., the 20% tolerance of 168 ft. may be applied at the near or far end of the simulator VGS or may be split between both as long as the total of 168 ft. is not exceeded.
b. Visual System Color	Demonstration Model				IR	IR	
c. Visual RVR Calibration	Demonstration Model				IR	IR	
d. Visual Display Focus and Intensity	Demonstration Model				IR	IR	
e. Visual Attitude vs. Simulator Attitude Indicator (Pitch and Roll of Horizon)	Demonstration Model				IR	IR	
f. Demonstrate 10 Levels of Occulting Through Each Channel of System	Demonstration Model				IR	IR	May be requested for recurrent evaluation.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
5. SIMULATOR SYSTEMS							
a. VISUAL, MOTION, AND COCKPIT INSTRUMENT RESPONSE							
Visual, Motion, and Instrument Systems response to an abrupt pilot controller input, compared to airplane response for a similar input.	150 milliseconds or less after airplane response.	Takeoff, Cruise Approach or Landing			IR	IR	One test is required in each axis (pitch, roll, and yaw) for each of the 3 conditions compared to airplane data for a similar input. (Total 9 tests.) Visual change may start before motion response, but motion acceleration must occur before completion of visual scan of first video field containing different information.
	300 milliseconds or less after airplane response.	Takeoff, Cruise, Approach or Landing	IR	IR			
or							
Transport Delay	150 milliseconds or less after control movement.	Pitch, Roll, Yaw			IR	IR	One test is required in each axis. (Total 3 tests.)
	300 milliseconds or less after control movement.	Pitch, Roll, Yaw	IR	IR			See Appendix 1, Item 2.v.
b. SOUND							
Realistic amplitude and frequency of cockpit noises and sounds, including precipitation static, and engine and airframe sounds. The sounds shall be coordinated with the weather representations required in FAR Part 121, Appendix H, Phase III (Level D), Visual Requirement No. 3.						IR	Test results must show a comparison of the amplitude and frequency content of the sounds that originate from the airplane or airplane systems.

TABLE OF VALIDATION TESTS (Cont'd)

I = Initial Evaluation
R = Recurrent Evaluation

Test	Tolerance	Flight Condition	Qualification Requirement A	B	C	D	Comments
c. DIAGNOSTIC TESTING							
(1) A means for quickly and effectively testing simulator programming and hardware. This could include an automated system which could be used for conducting at least a portion of the tests in the ATG.					IR	IR	
(2) Self testing of simulator hardware and programming to determine compliance with Levels B, C, and D Simulator Requirements.						IR	
(3) Diagnostic analysis as prescribed in FAR Part 121, Appendix H, Phase III (Level D) Simulator Requirement No. 5.						IR	

SIMULATOR VALIDATION TESTS (Cont'd)

3. CONTROL DYNAMICS. The characteristics of an airplane flight control system have a major effect on the handling qualities. A significant consideration in pilot acceptability of an airplane is the "feel" provided through the cockpit controls. Considerable effort is expended on airplane feel system design in order to deliver a system with which pilots will be comfortable and consider the airplane desirable to fly. In order for a simulator to be representative, it too must present the pilot with the proper feel; that of the respective airplane. This fact is recognized in FAR Part 121, Appendix H, Phase II (Level C) Simulator Requirement 10, which states: "Aircraft control feel dynamics shall duplicate the airplane simulated. This shall be determined by comparing a recording of the control feel dynamics of the simulator to airplane measurements in the takeoff, cruise, and landing configuration."

Recordings such as free response to an impulse or step function are classically used to estimate the dynamic properties of electromechanical systems. In any case, it is only possible to estimate the dynamic properties as a result of only being able to estimate true inputs and responses. Therefore, it is imperative that the best possible data be collected since close matching of the simulator control loading system to the airplane systems is essential. The required control feel dynamic tests dictated by FAR Part 121, Appendix H, are described in 2.b. of the Table of Validation Tests of this section.

For initial and upgrade evaluations, it is required that control dynamic characteristics be measured at and recorded directly from the cockpit controls. This procedure is usually accomplished by measuring the free response of the controls using a step or pulse input to excite the system. The procedure must be accomplished in takeoff, cruise, and landing flight conditions and configurations.

For airplanes with irreversible control systems, measurements may be obtained on the ground if proper Pitot-static inputs are provided to represent airspeeds typical of those encountered in flight. Likewise, it may be shown that for some airplanes, takeoff, cruise, and landing configurations have like effects. Thus, one may suffice for another. If either or both considerations apply, engineering validation or airplane manufacturer rationale must be submitted as justification for ground tests or for eliminating a configuration. For simulators requiring static and dynamic tests at the controls, special test fixtures will not be required during initial and upgrade evaluations if the operator's ATG shows both test fixture results and the results of an alternative approach, such as computer plots which were produced concurrently and show satisfactory agreement. Repeat of the alternative method during the initial evaluation would then satisfy this test requirement.

a. Control Dynamics Evaluations. The dynamic properties of control systems are often stated in terms of frequency, damping, and a number of other classical measurements which can be found in texts on control systems. In order to establish a consistent means of validating test results for simulator control loading, criteria

SIMULATOR VALIDATION TESTS (Cont'd)

are needed that will clearly define the interpretation of the measurements and the tolerances to be applied. Criteria are needed for both the underdamped system and the overdamped system, including the critically damped case. In case of an underdamped system with very light damping, the system may be quantified in terms of frequency and damping. In critically damped or overdamped systems, the frequency and damping is not readily measured from a response time history. Therefore, some other measurement must be used.

b. For Levels C and D Simulators. Tests to verify that control feel dynamics represent the airplane must show that the dynamic damping cycles (free response of the control) match that of the airplane within specified tolerances. The method of evaluating the response and the tolerance to be applied are described below for the underdamped and critically damped cases.

(1) Underdamped Response. Two measurements are required for the period, the time to first zero crossing (in case a rate limit is present) and the subsequent frequency of oscillation. It is necessary to measure cycles on an individual basis in case there are nonuniform periods in the response. Each period will be independently compared to the respective period of the airplane control system and, consequently, will enjoy the full tolerance specified for that period.

The damping tolerance should be applied to overshoots on an individual basis. Care should be taken when applying the tolerance to small overshoots since the significance of such overshoots becomes questionable. Only those overshoots larger than 5 percent of the total initial displacement should be considered significant. The residual band, labelled $T(A_d)$ on Figure 1 is ± 5 percent of the initial displacement amplitude A_d from the steady state value of the oscillation. Oscillations within the residual band are considered insignificant. When comparing simulator data to airplane data, the process should begin by overlaying or aligning the simulator and airplane steady state values and then comparing amplitudes of oscillation peaks, the time of the first zero crossing, and individual periods of oscillation. The simulator should show the same number of significant overshoots to within one when compared against the airplane data. This procedure for evaluating the response is illustrated in Figure 1.

(2) Critically Damped and Overdamped Response. Due to the nature of critically damped responses (no overshoots), the time to reach 90 percent of the steady state (neutral point) value should be the same as the airplane within ± 10 percent. The simulator response should be critically damped also. Figure 2 illustrates the procedure.

Tolerances

The following table summarizes the tolerances, T. See Figures 1 and 2 for an illustration of the referenced measurements.

$T(P_0)$	$\pm 10\%$ of P_0
$T(P_1)$	$\pm 20\%$ of P_1
$T(P_2)$	$\pm 30\%$ of P_2
$T(P_n)$	$\pm 10(n+1)\%$ of P_n
$T(A_n)$	$\pm 10\%$ of A_1, $\pm 20\%$ of Subsequent Peaks
$T(A_d)$	$\pm 5\%$ of A_d = Residual Band
	Overshoots ± 1

SIMULATOR VALIDATION TESTS (Cont'd)

c. Alternative Method for Control Dynamics. One airplane manufacturer has proposed, and the FAA accepts, an alternative means for dealing with control dynamics. The method applies to airplanes with hydraulically powered flight controls and artificial feel systems. Instead of free response measurements, the system would be validated by measurements of control force and rate of movement.

For each axis of pitch, roll, and yaw, the control shall be forced to its maximum extreme position for the following distinct rates. These tests shall be conducted at typical taxi, takeoff, cruise, and landing conditions.

(1) Static Test - Slowly move the control such that approximately 100 seconds are required to achieve a full sweep. A full sweep is defined as movement of the controller from neutral to the stop, usually aft or right stop, then to the opposite stop, then to the neutral position.

(2) Slow Dynamic Test - Achieve a full sweep in approximately 10 seconds.

(3) Fast Dynamic Test - Achieve a full sweep in approximately 4 seconds.

NOTE: Dynamic sweeps may be limited to forces not exceeding 100 lb.

Tolerances

(1) Static Test - Items 2.a.(1)(2) and (3) of this appendix.

(2) Dynamic Test - 2 lb. or 10 percent on dynamic increment above static test.

The FAA is open to alternative means such as the one described above. Such alternatives must, however, be justified and appropriate to the application. For example, the method described here may not apply to all manufacturers' systems and certainly not to airplanes with reversible control systems. Hence, each case must be considered on its own merit on an ad hoc basis. Should the FAA find that alternative methods do not result in satisfactory simulator performance, then more conventionally accepted methods must be used.

4. GROUND EFFECT. During landing and takeoff, airplanes operate for brief time intervals close to the ground. The presence of the ground significantly modifies the air flow past the airplane and, therefore, changes the aerodynamic characteristics. The close proximity of the ground imposes a barrier which inhibits the downward flow normally associated with the production of lift. The downwash is a function of height with the effects usually considered to be negligible above a height of approximately one wingspan. There are three main effects of the reduced downwash:

a. A reduction in downwash angle at the tail for a conventional configuration.

SIMULATOR VALIDATION TESTS (Cont'd)

b. An increase in both wing and tail lift because of changes in the relationship of lift coefficient to angle of attack (increase in lift curve slope).

c. A reduction in the induced drag.

Relative to out-of-ground effect flight (at a given angle of attack), these effects result in higher lift in ground effect and less power required for level flight. Because of the associated effects on stability, they also cause significant changes in elevator (or stabilizer) angle to trim and stick (column) forces required to maintain a given lift coefficient in level flight near the ground.

For a simulator to be used for takeoff and in particularly landing credit, it must faithfully reproduce the aerodynamic changes which occur in ground effect. The parameters chosen for simulator validation must obviously be indicative of these changes. The primary validation parameters for longitudinal characteristics in ground effect are:

a. Elevator or stabilizer angle to trim.

b. Power (thrust) required for level flight (PLF).

c. Angle of attack for a given lift coefficient.

d. Height/altitude.

e. Airspeed.

This listing of parameters assumes that ground effect data is acquired by tests during "fly-bys" at several altitudes in and out of ground effect. The test altitudes should, as a minimum, be at 10 percent, 30 percent, and 70 percent of the airplane wingspan and one altitude out of ground effect; e.g., 150 percent of wingspan. Level fly-bys are required for Level D, but not for Level C and Level B. They are, however, acceptable for all levels.

If, in lieu of the level fly-by method for Levels B and C, other methods such as shallow glidepath approaches to the ground maintaining a chosen parameter constant are proposed, then additional validation parameters are important. For example, if constant attitude shallow approaches are chosen as the test maneuver, pitch attitude, and flight path angle are additional necessary validation parameters. The selection of the test methods and procedures to validate ground effect is at the option of the organization performing the flight tests; however, rationale must be provided to conclude that the tests performed do indeed validate the ground effect model.

The allowable longitudinal parameter tolerances for validation of ground effect characteristics are:

Elevator or Stabilator Angle $\pm 1^\circ$

Power for Level Flight (PLF) $\pm 5\%$

SIMULATOR VALIDATION TESTS (Cont'd)

Angle of Attack	±1°
Altitude/Height	±10% or ±5' (1.5 m.)
Airspeed	±3 Knots
Pitch Attitude	±1°

The lateral-directional characteristics are also altered by ground effect. Because of the above-mentioned changes in lift curve slope, roll damping, as an example, is affected. The change in roll damping will affect other dynamic modes usually evaluated for simulator validation. In fact, Dutch-roll dynamics, spiral stability, and roll-rate for a given lateral control input are altered by ground effect. Steady heading sideslips will also be affected. These effects must be accounted for in the simulator modeling. Several tests such as "crosswind landing," "one engine inoperative landing," and "engine failure on takeoff" serve to validate lateral-directional ground effect since portions of them are accomplished while transiting altitudes at which ground effect is an important factor.

SIMULATOR VALIDATION TESTS (Cont'd)

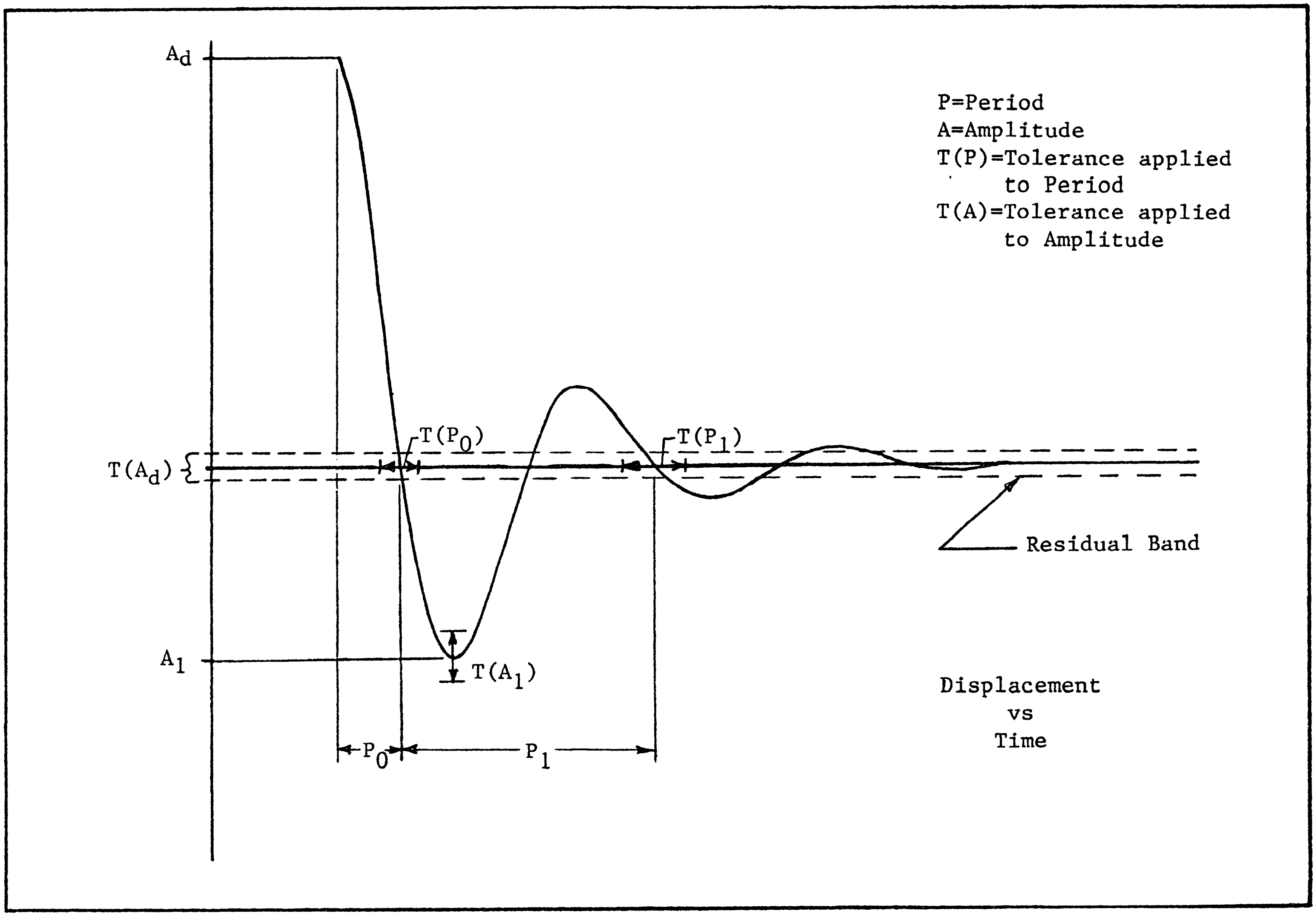

Figure 1. Under-damped Step Response

SIMULATOR VALIDATION TESTS (Cont'd)

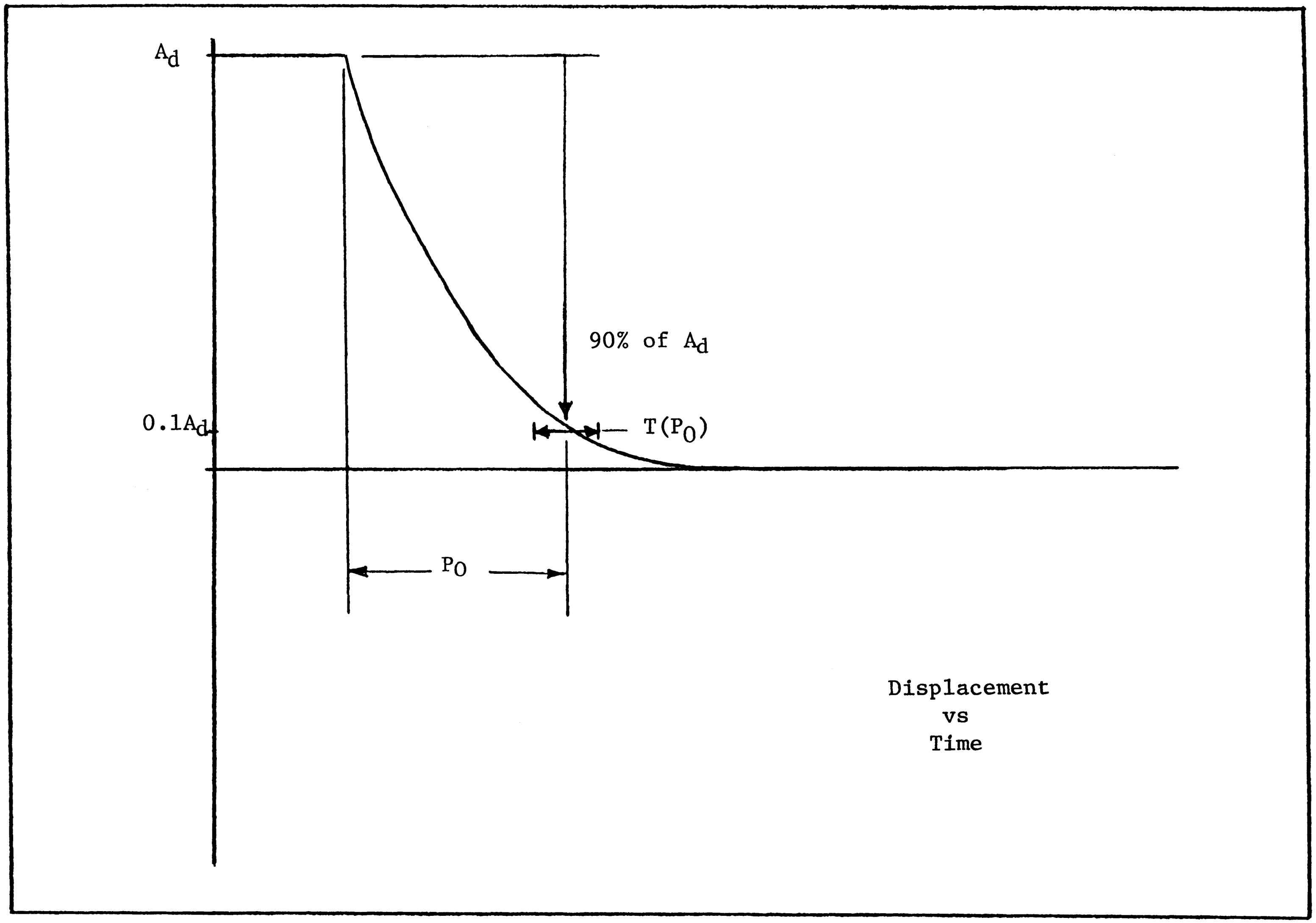

Figure 2. Critically-damped Step Response